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November 2002

ISSN 1342-3045

「国際開発研究」第11巻 第2号 抜刷 (pp. 173-186)
Journal of International Development Studies Vol. 11, No. 2

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2002年11月

The Japan Society for
International Development

国 際 開 発 学 会

[Report]

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Abstract

Developing countries are under increasing pressure to deal with a variety of environmental problems. These include industrial pollution, urban environmental issues, the deterioration of ecosystems, and global warming. At the same time, the countries are expected to achieve high economic growth. Therefore, developing countries urgently need to put maximum effort into their policies for improving environmental management and technology in order to overcome environmental difficulties.

This study focuses on the case of China, a typical example of a county facing environmental difficulties under high economic growth. It examines the income-environment relationship and environmental policy effects. Specifically, the two main questions are these: whether the environmental Kuznets curve (EK curve: in the course of economic development, the environment first gets worse, and then begins to get better) has been validated in China in such typical fields as air and water pollution, and to what extent China's environmental policies on pollution control have contributed to environmental improvements. The study's main findings are as follows: (1) a meaningful EK curve was verified for sulfur dioxide emission; and (2) environmental policy effects were identified in the sense that public resources, such as facilities for environmental treatment and manpower for environmental agencies, have an impact in reducing the relative level of sulfur emission against real income.

1. Introduction

Developing countries are at present facing two kinds of policy challenge: the challenges of economic development and of environmental conservation. In particular, developing countries in the process of industrializing are under pressure to deal simultaneously with a variety of environmental problems. These include industrial pollution, urban environmental issues, the deterioration of ecosystems, and global warming. At the same time, they are expected to achieve further economic development. In this context, therefore, developing countries urgently need to put maximum effort into their policies for improving environmental management and technology in order to overcome environmental difficulties.

This study focuses on the case of China, a typical example of a county facing environmental difficulties under high economic growth, and it examines the income-environment relationship and environmental policy effects. Specifically, the two main questions are these: whether the environmental Kuznets curve (EK curve: in the course of economic development, the environment first gets worse, and then begins to get better) has been validated in China

Journal of International Development Studies, Vol.11. No.2, 2002, pp. 173-186

in such typical fields as air and water pollution, and to what extent China's environmental policies for pollution control have contributed to environmental improvements. The findings shown below from empirical tests support the existence of the EK curve for one selected pollutant and of environmental policy effects with selected variables.

In the following sections, we will first outline the recent trends in the state of the environment and in policy in China, focusing on air and water pollution (Section 2); then we review previous studies on that topic (Section 3), conduct our own empirical study of the EK curve as it applies to China and of policy effects (Section 4), and we end with concluding remarks (Section 5).

2. Environmental trends and policy in China

We here outline recent environmental trends and policy in China, focusing on air and water pollution(1).

2.1. Environmental trends

China's growth, while improving living standards, has brought serious damage to its environment. China's air and water, particularly in urban areas, are among the most polluted in the world. Ambient concentrations of most pollutants exceed international standards several times over, burdening China with vast human and economic costs. The economic costs of China's air and water pollution have been estimated at 3-8 percent of GDP a year (World Bank 1997a and 1997b).

Two forces are responsible for much of China's environmental degradation. The first is China's extreme dependence on coal. Today, coal satisfies nearly 80 percent of China's demand for energy, making China the world's largest coal consumer. The second factor is China's booming cities. Rising urbanization, accompanied by increased automobile use and largely untreated emissions of municipal waste, has increased the portion of the population exposed to the greater pollution found in urban areas.

The government has recognized the environmental challenges confronting the country, and over the past decade has established environmental authorities and introduced a comprehensive legal framework to protect the environment and it has invested considerable resources in protecting air and water. It is said that these efforts can claim some successes(2), but much remains to be done. Details on pollution control policies in China are given below.

2.2. Pollution control policies

Over the past decade, the government has introduced a comprehensive legal framework to protect the environment and it has established environmental authorities. To start with, the government formulated an official basic law: the Environmental Protection Law, as an experimental law in 1979. It was substantially revised and re-enforced in 1989. This was followed by the formulation and revision of several specific laws for preventing air pollution, water pollution, solid waste pollution and so on. In 1984, China established the State

Environmental Protection Commission, which formulates national environmental policies and regulations and reports directly to the State Council. The commission is supported by the independent State Environmental Protection Administration, which disseminates environmental policy and regulations, collects environmental data, provides training and support to local environmental protection bureaus, and advises the commission on environmental policy.

China's pollution control policies are based on three main principles, administered through eight regulatory programs. The three principles emphasize: 1) prevention first, then prevention with control, 2) polluters pay, and 3) a strong regulatory framework. Eight programs form the core of China's environmental protection activities: environmental impact assessments, the Three Synchronizations program(3), pollution levies, pollution discharge permits, mandatory pollution controls, centralization of pollution control, the goal-responsibility system of environmental protection, and the quantitative appraisal system for comprehensive urban environment control. We here reorganize the above programs into three categories of prevention, control and monitoring and enforcement, and explain them briefly as follows.

Prevention. Pollution prevention focuses on new pollution sources, which are regulated through environmental impact assessments and the Three Synchronizations program. The program mandates that new industrial enterprises and existing enterprises that plan to expand or change their production process receive environmental impact assessment approval for their plans from its authorities.

Control. Pollution from existing sources is regulated through pollution levies, pollution discharge permits, and mandatory pollution controls. Pollution levies were introduced in 1983 to create an economic incentive for industrial enterprises to comply with emission and effluent standards, to raise revenue for investment in industrial pollution control, and to provide financial support for regulatory activities. Discharge permits were introduced in 1987 to reinforce the mechanisms to control total pollution loads. The government has experimented widely with permits to control water pollution but has not used them much to control air pollution. Mandatory pollution controls have been used as a last resort to force highly polluting enterprises to adopt control measures(4).

Monitoring and enforcement. National and local environmental regulations and standards are enforced primarily by municipal and county environmental protection bureaus, which report to local governments. In general, medium-size and large enterprises are monitored by the bureaus once or twice a year, while small enterprises are monitored less often.

3. Previous studies

Corresponding to our empirical studies later on, we here review the previous studies on the topics of 1) the EK curve and 2) the effects of China's environmental policies.

3.1. Environmental Kuznets curve: theoretical background

The EK curve provides an analytical framework to examine how economies deal with environmental issues. The EK curve hypothesis suggests that in the course of economic development, the environment gets worse before it gets better. We first outline the theoretical background for the EK curve by summarizing Panayotou's explanations (Panayotou 1995).

Panayotou (1995) showed the following two reasons why environmental degradation rises at first and then falls in the course of economic development. First, the state of natural resources and the environment in a country depends on the structure of its economy. There are fairly close relationships between the level of development and the share of the industrial sector in GDP. At the low-income stage, the share of industry in GDP is small (less than that of agriculture)—dominated by agro-processing and light manufacturing. At the middle-income stage, industry's share approaches or exceeds one-third of GDP; the relationships, however, are not linear. At the higher-income stage, the share of industry stabilizes or declines somewhat, dominated by more sophisticated technology industries. Industrial emissions vary with the size of the industrial sector. At the later stage of development, the share of the industrial sector within total GDP levels off and begins to decline gradually. These structural changes alone may explain the inverted relationship between emissions and the level of economic development.

Second, as incomes grow, people can afford to become more environmentally-conscious; environmental regulations are tightened and more strictly enforced. Environmental quality is an income-elastic "commodity" that does not constitute a significant part of the consumer's budget until fairly high levels of income have been attained. Only after the higher levels of income and wealth are consolidated economically does the demand for environmental quality (being income-elastic) rise. As a result, economic, social, and political pressures are built up to institute and enforce environmental regulations and to increase budgetary allocations for environmental protection. Thus, in the later stages of development, environmental quality improves.

3.2. Environmental Kuznets curve: previous studies

A summary of previous studies of the EK curve follows. The issue of the EK curve was first discussed in the World Bank's 1992 World Development Report (World Bank 1992). The report described a cross-sectional EK curve for concentrations of sulfur dioxide. Since the World Bank's report, there have been numerous theoretical debates and empirical tests of the EK curve. Empirical evidence has grown supporting the EK curve for some regions and some environmental problems. Grossman and Krueger (1995) found an EK curve relationship between per capita GDP and urban sulfur dioxide (SO_2) concentrations. A similar relationship was found for air particulates in cities, and fecal coliform and arsenic in rivers (Islam 1996).

Despite these results, it is prudent to resist the temptation to elevate the EK curve hypothesis to a universal law of development[(5)]. There is a substantial body of empirical work that rejects the EK curve hypothesis. In addition, research is limited to the class of environmental problems for which data exist, such as the concentration of pollutants in urban areas. We are not aware of empirical analyses of the relationship between income and the degradation of key ecological services.

Most of the empirical studies for validating the EK curve hypothesis so far have concentrated on developed countries and have not extended to the case of developing countries. Matsuoka et al. (2000) and Taguchi (2001) examined the EK curves of selected Asian countries and explained the differences in the height of the EK curves by citing the latecomers' advantages as arising from the dissemination of environmental monitoring systems in Asian countries. Case studies on such individual developing countries as China, however, have not yet been found.

3.3. The case of China: policy analyses

We now turn to reviewing previous studies on the effects of China's environmental policies. Quantitative studies have been available for policy effects assessment in specific fields but not for an overall comprehensive assessment. China's pollution levy, for example, has been intensively studied for its effectiveness as a pollution control instrument, because it may be one of the few economic instruments with a long, documented history of application and without peer in the world in its sheer magnitude.

There have been have been a variety of views on China's experience with the pollution levy. There are claims that marked differences exist in the degree of enforcement across regions. Observations have created the impression that the current administration of the system, while improving, remains relatively arbitrary (Qu, 1991). The incentive properties of the system have also been called into question: case studies have been used to support the claim that levy rates are generally below the marginal cost of abatement needed for compliance with China's emissions standards. Drawing on this evidence, some critics have asserted that the levy rates are too low to have significant effects on industrial emissions (Qu, 1991; NEPA, 1992 and 1994; Shibli and Markandya, 1995).

Wang and Wheeler (1996) tested the above-mentioned conventional critique of the levy system using a province-level database for the period 1987-1993. They analyzed the water pollution levy whose implementation and impact are well-documented in the information available. Their results suggested that the water pollution levy system was neither arbitrary nor ineffective: across provinces and over time, variations in the effective levy rate are well-explained by proxies for local valuation of environmental damage and community capacity to enforce local norms. Their results also suggested that the emissions intensity of Chinese industry was highly responsive to increases in the effective levy rate, because marginal abatement costs were actually lower than levy rates in many cases. The World Bank (1997a) studied the relationship between regulatory strictness and pollution intensity, using the effective levy as a proxy for all the regulations applied to industrial enterprises. They suggested that effective levies have had significant effects on the pollution intensity of production across China's provinces.

4. Empirical studies

We next turn to empirical analyses of the Environmental Kuznets curve and policy effects in China. There are two steps to the analyses. First, we verify the existence of the EK curve,

Table 1. Sample Characteristics

	Sample mean	Standard deviation	Number of observation[a]
⟨Analysis on EK curves⟩			
Sulfur dioxide (gram per capita)	$1.24 * 10^4$	$8.17 * 10^3$	270
Industrial Dust (gram per capita)	$6.35 * 10^3$	$3.61 * 10^3$	270
Waste water discharged (gram per capita)	$1.88 * 10^7$	$1.39 * 10^7$	270
Real income per capita (yuan per capita, 1996 prices)	$4.80 * 10^3$	$4.27 * 10^3$	270
⟨Analysis on policy effects⟩			
Sulfur dioxide			
(gram per capita)	$1.26 * 10^4$	$8.11 * 10^3$	120
(gram per yuan, 1996 prices)	2.37	2.16	120
Industrial ratio (% of GDP)	36.5	9.16	120
Facilities for treatment of waste gas (per 1,000 persons)	$1.13 * 10^{-1}$	$7.04 * 10^{-2}$	120
Staff & Workers for environmental agencies (per 1,000 persons)	$9.69 * 10^{-2}$	$3.77 * 10^{-2}$	120

Note:
a) Region(30) : Beijing, Tianjing, Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang.
Estimated period : 1991-1999 for analysis on EK curves, 1996-1999 for analysis on policy effects.
Sources : China Statistical Yearbook 2000.

the inverted-U relationship in China's income-environment relationship. We do this analysis on three kinds of pollutants: sulfur dioxide emission, industrial dust emission and waste water discharge, because these pollutants are often used as indicators of environmental quality and the data on them are available. Second, we analyze the effects of China's environmental policies for pollution control. In this analysis, we focus on the sulfur dioxide emission in which the EK curve was verified in the first step. In both steps, we conduct regional survey to examine provincial environmental states. We construct a table of annual environmental and economic data from 30 Chinese provinces for the data-available period. All sample data come from the China Statistical Yearbook. The means and standard deviations for all the variables used in estimation are provided in Table 1.

4.1. China and the Environmental Kuznets curve

We now examine the existence of the EK curve in China's income-environment relationship. We first clarify methodological issues in our analysis.

4.1.1. Methodological issues

To study the existence of the EK curve, we estimate the following reduced-form equations that relate the level of pollution (air or water) to income per capita.

(1) $PC_{it} = a_0 + a_1\ Y_{it} + a_2\ Y^2_{it} + e_{it}$

where PC_{it} is a measure of air or water pollution per capita in area i in year t, Y_{it} is real income per capita in area i in year t, and e_{it} is an error term. The a's are parameters to be estimated.

For the air pollutants we use sulfur dioxide emission and industrial dust emission, while for the water pollutants we use waste water discharge in each area over the course of years.

Of particular importance are the signs and magnitudes of a_1 and a_2 in (1). Pollutants can be said to exhibit a meaningful EK curve with real income per capita if $a_1 > 0$ and $a_2 < 0$ and if the turning point, $-a_1/2a_2$ is a reasonably low number.

A basic issue to address is the exclusion from Equation (1) of explanatory variables other than real income per capita. It is important in this regard to distinguish between variables that are the endogenous consequences of growth and other, more exogenous factors. Potential examples of the former include the composition of output, the level of education, and the political structure. These factors should be omitted from this single-equation model, insofar as our objective is to assess both the direct and the indirect consequences of growth. In other words, to the extent one can speak of a "development path" that involves a systematic relationship among these variables and per capita real income growth, one would want to exclude these variables from the analysis.

Of course, there are also likely to be exogenous factors that affect pollutants. For instance, climate and geography vary widely among areas and may well be correlated with pollutants. Insofar as these factors cause the error terms in (1) to be correlated among areas for a given period, pooled cross-section estimates that ignore this correlation will be in efficient.

To address this issue, we specify an error-components model in which

(2) $e_{it} = r_i + u_{it}$

where r_i is a regional effect, and u_{it} is the remaining error term. Because we assume that an area-specific component is correlated with real income per capita, we employ a fixed effects estimator with cross section weights.

Table 2. The Results of Fixed Effects Estimation for the EK curves in China (t−value in parentheses)[a]

Variale	Sulfur	Dust	Waste water
Constant [b]	$1.16 * 10^4$	$4.70 * 10^3$	$2.17 * 10^7$
Real Income per capita (Y)	$2.53 * 10^{-1}$***	$3.77 * 10^{-1}$***	$-3.59 * 10^{2}$***
	(5.89)	(3.92)	(−5.27)
Squared Real Income per capita (Y^2)	$-1.08 * 10^{-5}$***	$-3.83 * 10^{-6}$	$-2.79 * 10^{-2}$
	(−4.16)	(−0.62)	(−6.45)
Adj R**2	0.87	0.77	0.98
Turning point	$1.17 * 10^4$	$4.92 * 10^4$	$-6.44 * 10^3$

Note :
a) One, two, or three asterisks indicate that a coefficient estimate is significantly differen from zero at 10, 5, or 1% percent level, respectively.
b) Constant terms include the mean of the estimated country effects.
Source : the same as Table 1.

4.1.2. Main findings

We have estimated equation (1) for each of the pollutants. The results of fixed effects estimation are reported in Table 2.

In the case of sulfur dioxide emission per capita, the estimates of main parameters of interest, a_1 and a_2 have the expected signs and are typically different from zero at high levels of significance. In addition, the turning point indicates a feasible number, which will be analyzed in the following section. Sulfur dioxide emission can, therefore, be said to show a meaningful EK curve with real income per capita. For industrial dust emission, the estimated parameters of a_1 and a_2 have the expected signs. But the parameter of squared real income per capita, a_2, is not discernable and the turning point seems to be too high. Therefore, industrial dust emission cannot be said to hold the EK curve and may be in the positively-sloping part of the EK curve in the sample area and period. The waste water discharge has significant parameters of a_1 and a_2, but does not have the expected sign in the real income per capita, thereby having a negative number of turning point. Waste water discharge, therefore, cannot be said to have a meaningful EK curve in the sample area and period. It is only in the case of sulfur dioxide emission that a meaningful inverted U-shape of the EK curve is verified.

4.1.3. Regional Survey

We further examine the EK curve from the regional point of view, focusing on the sulfur dioxide emission in which the nation-wide EK curve was identified previously. Figure 1 describes the income-sulfur relationships in 1991-1999 of eleven provinces with real income per capita of more than 7,000 yuan in 1999, near to the nation-wide EK curve's turning point of 11,700 yuan.

In the area over the nation-wide turning point, we find the negatively-sloping part of the EK curves of three high-income provinces of Shanghai, Beijing and Tianjing. These three

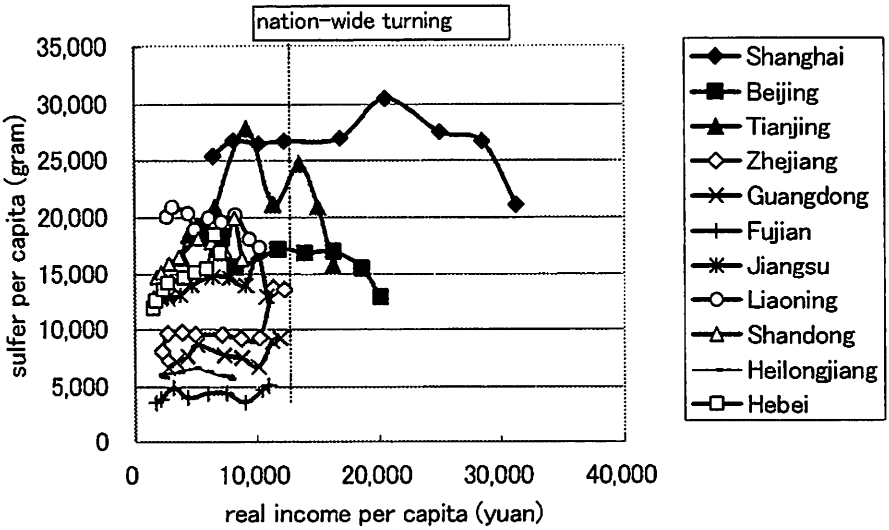

Figure 1. Income-sulfur Relationship in 1991-1999 of selected provinces

provinces seem to have full shape of the EK curve. In the area below the turning point, most of regional curves appear to show positive slope although their locations are different. The curves of other provinces (which are omitted from Figure 1) do not have a noteworthy characteristic as a group.

4.2. Effects of China's environmental policies

We now turn to the analysis of the effects of China's environmental policies for pollution control on environmental improvements. In this analysis, we focus on the sulfur dioxide emission in which the EK curve was verified in the previous section, and examine whether environmental policies have contributed to the decline of sulfur emission per capita shown in the EK curve. We here use the data only for 1996-1999 as shown in Table 1, because of the data constraint on the facilities for treatment of waste gas. We start with methodological issues.

4.2.1. Methodological issues

We estimate the following reduced-form equations that relate sulfur emission to explanatory variables including the factors of environmental policies. We select explanatory variables considering the theoretical background for the EK curve (shown in Section 3.1) and data availability.

(3) $SC_{it}=b_0+b_1\ IND_{it}+b_2\ FAC_{it}+b_3\ MAN_{it}+e_{it}$

(4) $SI_{it}=c_0+c_1\ IND_{it}+c_2\ FAC_{it}+c_3\ MAN_{it}+e_{it}$

where SCit is sulfur dioxide emission per capita in area i in year t, SI_{it} is sulfur dioxide emission per real income, INDit is industrial ratio relative to GDP, FAC_{it} is facilities for treatment of waste gas, MANit is staff and workers for environmental agencies, and e_{it} is an error term. The b's and c's are parameters to be estimated.

For measures of sulfur emission we use two kinds of indicators (SC and SI): sulfur emission per capita and sulfur emission per real income. The former is for seeing the absolute level of pollution per capita, while the latter is for seeing the relative level of pollution against real income, which corresponds to the slope of the EK curve.

The signs of b_1 and c_1, parameters of industrial ratio are expected to be positive, and those of b_2, b_3, c_2 and c_3, parameters of facilities and staff and workers (namely, environmental policy factors) to be negative. Environmental policy effects can be identified if these parameters of b_2, b_3, c_2 and c_3 are significantly negative.

We employ a fixed effects estimator with cross section weights as in the previous section, because we assume the existence of area-specific factors that affect the pollutant and that are correlated with explanatory variables.

4.2.2. Main findings

We have estimated equation (3) and (4). The results of fixed effects estimation for environmental policy effects are reported in Table 3.

The estimation of sulfur emission per capita shows that all the coefficients are significant, but does not have the expected signs for facilities and staff and workers. It appears that environmental policies produce an adverse effect on the absolute level of sulfur emission. We may rather interpret that those public resources such as facilities and manpower are intensively allocated in heavily polluted areas and periods.

The equation (a), (b) and (c) on sulfur emission per real income indicates that all the

Table 3. The Results of Fixed Effects Estimation for China's Environmental Policy Effects (t-value in parentheses)[a]

	Sulfur per capita	Sulfur per real income		
		(a)	(b)	(c)
Constant[b]	$-5.92 * 10^{3}$	$2.55 * 10^{-1}$	$1.44 * 10^{-1}$	3.87
Inductrial ratio	$3.52 * 10^{2***}$	$7.19 * 10^{-2***}$	$7.16 * 10^{-2***}$	$1.21 * 10^{-1***}$
	(4.06)	(4.44)	(4.51)	(4.70)
Facilities	$3.52 * 10^{4***}$	-3.09^{***}	-3.40^{***}	
	(8.75)	(−2.61)	(−2.98)	
Staff & Workers	$1.75 * 10^{4**}$	−1.59		$-4.85 * 10^{***}$
	(2.27)	(−0.80)		(11.97)
Adj R^{**2}	0.97	0.92	0.93	0.61

Note :

a) One, two, or three asterisks indicate that a coefficient estimate is significantly different from zero at 10, 5, or 1% percent level, respectively.

b) Constant terms include the mean of the estimated country effects.

Source : the same as Table 1 .

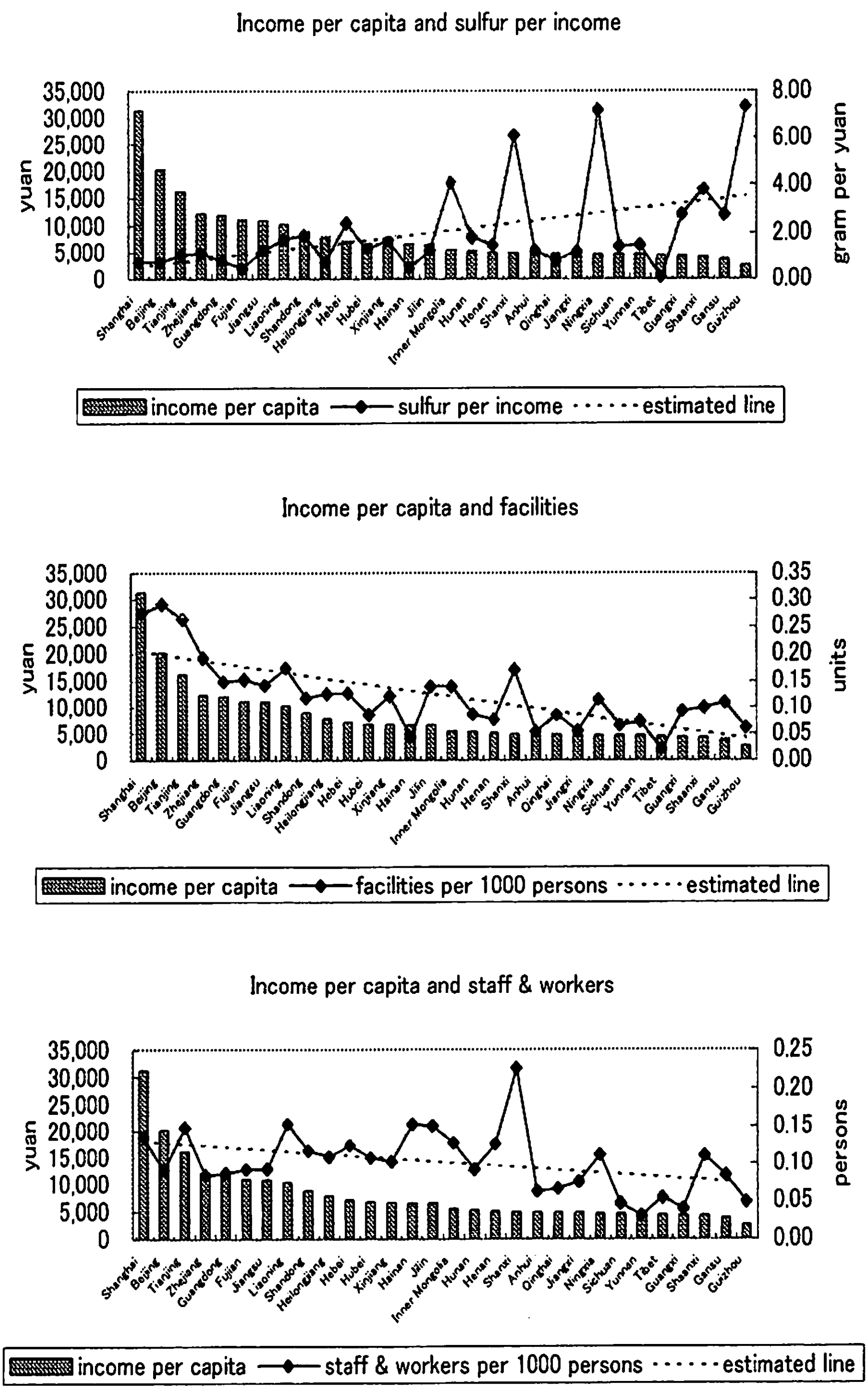

Figure 2. Income, sulfur emissions and policies in 1999 by provinces

parameters have the expected signs and significant values except the staff and workers in (a). It seems that those public resources such as facilities and manpower do have an effect on mitigating the relative level of sulfur emission against real income. In other words, policy variables above may at least have some impacts on flattening the slope of the identified EK curve for sulfur dioxide emission.

We speculate that as far as those variables such as environmental facilities and manpower are concerned, policy effects are verified not in absolute but in relative levels of sulfur dioxide emission.

4.2.3. Regional Survey

We further examine the relationship between environmental policies and sulfur emission per real income from the regional point of view. Figure 2 lines provinces up in order of real income per capita in 1999, and describes sulfur emission per real income, facilities for treatment of waste gas per 1,000 persons and staff and workers for environmental agencies per 1,000 persons of each province.

We find from Figure 2 that the richer the provinces are, the lower their sulfur emissions per real income are and the more facilities and workers are allocated for environmental policies. From this observation, we speculate that the richer provinces can afford to allocate public resources for environmental preservation, and then mitigate sulfur dioxide emissions relative to real income. This outcome is consistent with that of the regression analysis in the previous session.

5. Concluding remarks

In this study we set out to examine, using empirical studies (Section 4), whether the EK curve has been validated in China-in such typical fields as air and water pollutions, and to what extent China's environmental policies for pollution control have contributed to environmental improvements.

We first verified the existence of a meaningful inverted U-shape of the EK curve for real income per capita and sulfur dioxide emission, though not for industrial dust emission and waste water discharge. Second, focusing on sulfur emission with the identified EK curve, we identified environmental policy effects in the sense that public resources such as facilities and manpower have an impact on reducing the relative level of the pollutant against real income.

This study, however, is only the beginning of an analysis of China's environmental policy effects. Analytical issues still remain that need to be addressed. First, environmental degradation involves a wide variety of pollutants and ecosystems, therefore, empirical tests are needed on emissions and factors other than sulfur, industrial dust and waste water. Second, analytical method for identifying environmental policy effects needs to be developed further. For example, this paper narrows the focus considerably by selecting facilities for treatment and staff and workers for environmental agencies as policy variables. By examining such comprehensive policy factors as pollution levies and discharge permits described in Section 2.3, the regression analysis would be made broader and more robust. Further studies in this field will provide significant information to allow for improved planning and evaluation of environmental policies.

Acknowledgement

We are grateful to Mr. Eiichi Sekine, who provided us with necessary data for this empirical study.

Notes

(1) The descriptions in this section mostly refer to World Bank (1997a and 1997b).
(2) For example, World Bank (1997a, chapter 5) shows that pollution intensities-emissions per unit of output-have fallen in recent years in China.
(3) The Three Synchronizations Program mandates that a project and its pollution control facility be designed, built, and operated in synchronization.
(4) A mandatory air pollution control was reinforced in 2000. The Law of Air Pollution Prevention and Control was revised in such a way that emitted pollution exceeding standards is an irregularity instead of only being charged. See CNEMC (2001).
(5) For details on criticism of the EK curve hypothesis, see Asian Development Bank (2000).

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